SEE Bulletin

Developing Tomorrow's Space Technologies Today

NASA's Space Environments and Effects Program

Fall 1997 Issue

NASA Participation in Space Technology Research Vehicle

With the current trend of the "smaller, better, cheaper, faster" philosophy, spacecraft systems are increasingly using commercial off-the-shelf (COTS) technologies for satellite applications. The feature size of these modern microelectronics continually decreases while the component density increases. These practices increase the radiation sensitivity, causing concerns for attaining reliable performance of the electronics. In the last 25 years, numerous spacecraft

anomalies have been attributed to effects from radiation. Only flight experiments can provide the necessary data to improve the predicted performance capabilities for future missions. The Space Technology Research Vehicle-1d (STRV) mission contains specific flight experiments to better understand the space radiation environment and its effects on the electronics. The objectives are to provide low-cost access to space for flight validation of microelectronic devices and to develop validation protocol/test matrices to minimize the uncertainties between ground radiation test results and space results.

The United Kingdom's Defense Evaluation and Research Agency (DERA) will launch the STRV-1d on an Ariane-5 launch vehicle early in 1999, corresponding to solar maximum which occurs every 11 years. It will have a fully operational life of 1 year. The satellite will be delivered to an elliptical orbit, with perigee at 620 km and apogee at 36,000 km, an inclination of 7 degrees, and an orbital period of about 10.5 hours. This is an especially harsh orbit in terms of radiation. During each orbit, it will pass through the Van Allen Belts, which consists of a trapped proton region and an inner and outer electron belt. The charged particles in these belts cause serious problems for satellite operations.

NASA is preparing 5 flight experiments to fly aboard the STRV-1d mission to evaluate the effects of the space radiation environment on electronics. These 5 experiments comprise the NASA Space Radiation and Electronics Testbed (NASRET). NASA's Space Environments and Effects (SEE) program, managed by the Marshall Space Flight Center, is leading this effort with major participation from:

- National Aeronautics and Space Administration Headquarters (NASA HQ)
- Goddard Space Flight Center (GSFC)
- Jet Propulsion Laboratory (JPL)
- Langley Research Center (LaRC)
- Aerospace Corporation

The NASA experiments, among others, will be located on the Electronics Test Bed (ETB), which is being developed and integrated by the Ballistic Missile Defense Organization (BMDO). The goals of the ETB are to reduce size, weight, power, cost, and production time for future spacecraft as well as to increase their reliability. This will be achieved by collecting flight data and ground test data for advanced and COTS microelectronic components and collecting on-orbit ionizing radiation environment data. Flight and ground data will be used to improve single event effects rate

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billy.kauffman@msfc.nasa.gov

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1997 Spacecraft Contamination & Coatings Workshop

Philip Chen, Goddard Space Flight Center

The 1997 Spacecraft Contamination & Coatings Workshop was held on July 9 and 10, 1997, at the Historic Inns of Annapolis in Annapolis, MD. The workshop was sponsored by the Space Environments and Effects (SEE) Program and organized by the Thermal Engineering Branch (Code 724) at Goddard Space Flight Center (GSFC). The SEE program is a major activity under the Advanced Technology and Missions Studies Division of the NASA Office of Space Science. The objective of the workshop was to provide a forum for exchanging new developments in spacecraft contamination and coatings.

The contamination presentations covered the first one and a half days and included overall policy, control engineering, mission experience, modeling, hardware, requirements, flight data, and testing. The coatings presentations were a half day on the second day and included new technologies, facilities, and testing. Approximately 130 people attended the Workshop and participated in the technical sessions and round table discussion. Presenters and attendees at the workshop represented government agencies, industry, and universities concerned with spacecraft contamination and coatings engineering, including NASA, JPL, DoD, Boeing, McDonnell Douglas, Lockheed, and Phillips Laboratory, to name just a few. The keynote speech was delivered by Dr. Peter Ulrich, Director of the Advanced Technology and Missions Studies Division at NASA Headquarters. The Workshop has received considerable positive feedback and, as a result, will probably continue to be held on a regular basis. The presentation materials are being compiled and published as proceedings for distribution to attendees and interested parties.

The workshop was organized by Drs. Philip Chen and Steve Benner of the Thermal Engineering Branch at the GSFC. Four technical sessions were chaired by

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Design Guidelines for Shielding Effectiveness, Current Carrying Capability, and the Enhancement of Conductivity of Composite Materials (NASA CR 4784)

By Ross Evans, Computer Sciences Corporation/MSFC

The NASA Space Environments & Effect (SEE) Program funded a task to develop electromagnetic compatibility (EMC) guidelines for spacecraft using composite materials. The task consisted of fault current and lightning tests to determine effects on composite materials and joints and a literature review primarily for shielding information.

Shielding effectiveness depends largely upon the conductivity of the material. Graphite epoxy can provide useful shielding against RF signals even though it is about 1000 times more resistive than the most conductive metals. The shielding effectiveness of vehicle skin or equipment cases with metal walls of any reasonable thickness is limited by the apertures, joints, and other discontinuities, rather than the metal itself. Shielding effectiveness of graphite epoxy material may approach that of the apertures in the enclosure depending on the conductivity of the material. When shielding is required of composite material enclosures, calculation of the shielding effectiveness of the composite material as well as the apertures should be made. Calculation methods and estimates of shielding effectiveness based on the conductivity of the material are described in NASA CR 4784.

The current carrying capability of graphite epoxy is adequate to dissipate static charges, but higher current through graphite epoxy may ignite the material. Tests were performed to determine the current carrying capability of graphite epoxy in case a power line shorted to the material. The tests showed that graphite epoxy could carry up to 5 amps of fault current. Above this value, smoke, sparks, and flame developed at the shorting point, the current exit point, and at joints where the area of electrical contact was restricted. Graphite epoxy should not be used for intentional circuit return. Any composite should undergo current carrying tests before use in a spacecraft where a power short to the material may occur or where a short circuit return current must pass through the material. One sample of high temperature graphite-phenolic material did not burn when subjected to 30 amps of current. However, any of the composite materials may have enough resistance, especially where several joints are involved, to limit fault current to levels below those required to blow a circuit breaker or fuse. Further test results can be found in the Test Report — Fault Current Through Graphite Filament Reinforced Plastic, NASA CR 4774,

In the area of lightning protection, simulated lightning strikes were used to test various thicknesses of graphite epoxy and joints between samples. Some of the samples had one or two expanded metal foil layers as an enhancement to conductivity. Generally the top few layers were burned, and shock damage went deeper into the composite material. Sacrificial expanded metal foil as a top layer reduces damage to underlying composite layers. A second expanded foil or screen layer on the bottom provides shielding against high frequency electromagnetic fields induced by the lightning current. Of the samples tested, the combination of screen or foil on both sides produced the best protection against lightning. However, a layer of aluminum honeycomb between two layers of composite material does not work well; the lightning current passes through the composite material, expands the honeycomb, and blows the composite layers away from the honeycomb. A fire hazard is also present just as it is with fault current. Test results and photos of the test samples are published in the Test Report — Direct and Indirect Lightning Effects on Composite Materials, NASA CR 4783

When composite material is being considered for spacecraft use, trade studies should include the added weight and effort necessary to make the material meet shielding, fault current, or lightning requirements.

Note: Copies of the NASA Contractor Reports may be obtained by contacting the SEE Program Office by e-mailing Billy Kauffman at: billy.kauffman@msfc.nasa.gov. The reports should be available by November 1st, 1997.

Meteoroid and Debris Database

Thomas See, Johnson Space Center

With the aid of some funding from the SEE Program Office (Marshall Space Flight Center, MSFC), members of the SEE Meteoroid & Debris (M&D) Technical Working Group at the Johnson Space Center (JSC) in Houston, Texas have revised and updated the user access to the Meteoroid & Debris Database that is maintained at JSC. Until recently, database access was accomplished via a TELNET connection to a VAX computer, leading the user to a DOS-type, character-based interface and search routines. However, over the past several years, database access and searching via a Web Browser (i.e., graphical user interface, GUI) have replaced these older, character-based systems as the norm. To accommodate this change, the M&D Database has been revised such that access and searches can be accomplished via a Web Browser interface.

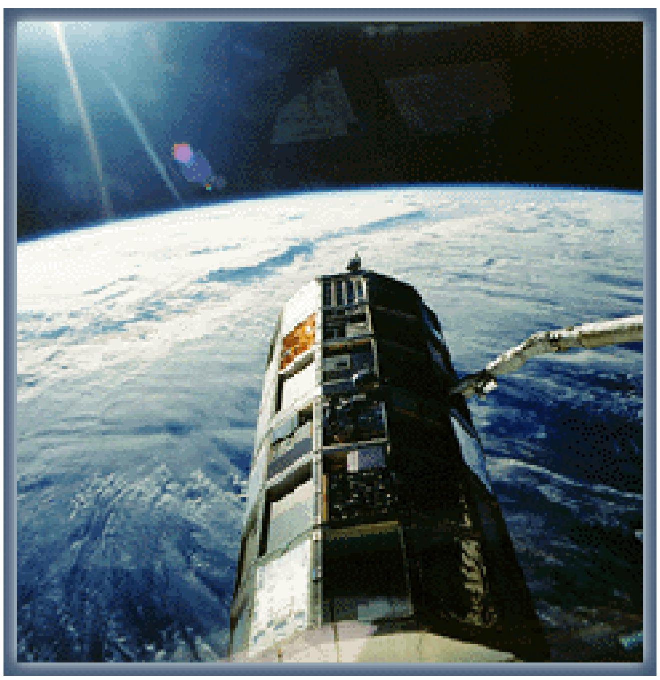
The M&D Database contains over 20,000 records of information related to impacts documented on the Long Duration Exposure Facility (LDEF) spacecraft, which spent ~5.7 years in Earth orbit. The database contains information on features documented at the Kennedy Space Center (KSC) during LDEF deintegration and in 1990, data generated at JSC over several years following LDEF's return, as well as data provided by various Principal Investigators from specific experiments.

Access to and use of the data contained within the M&D Database is encouraged. As JSC will remain the central repository for such information, investigators are encouraged to continue to send similar data for inclusion with this extensive M&D Database. Investigators possessing such data should contact T.H. See (thsee@ems.jsc.nasa.gov) or M.E. Zolensky (mzolensk@ems.jsc.nasa.gov) at JSC to discuss details regarding the formatting and submission of the data for inclusion in the M&D Database.

The M&D Database is accessible over the Internet at the following URL; no username or password is required:

http://sn-charon.jsc.nasa.gov/dbsearch/ldef/SearchMenu.htm

Once there, the user will find two links, one to conduct on-line searches, the other to access the database download area. The difference between the on-line search results and downloads is:



The ***on-line search*** encompasses all 22,365 records of the database and has the potential to overload an end-user's machine, causing it to lockup or freeze for long periods of time (see **Search Area,** below). Information presented to a user's screen is printable, but cannot be output to a file that does not include all of the HTML code. This means that considerable clean up of such a saved file would be required before the data could be imported into a spreadsheet or database application.

The ***downloads***, on the other hand, offers the user the ability to download the entire database, or one of several data subsets (see **Downloads Area,** below). The downloaded file can easily be imported into a spreadsheet or database application, where the user can do what ever they please with the data. The three, downloadable subsets (i.e., Intercostals, Space Debris Impact Experiment, & Chemistry of Micrometeoroids Experiment) contain the best, and most statistically significant and complete data sets from all of LDEF. These three data sets alone contain over 15,000 impact records, or nearly 70% of the entire database, in a form that is ideally suited for use by interested parties.

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1997 Spacecraft Contamination & Coatings Workshop

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Ms. Eve Wooldridge, Ms. Sharon Straka, Mr. Randy Hedgeland, and Mr. Lon Kauder of GSFC. Administrative and logistics support was provided by Ms. Jessica Katz of GSFC and Ms. Sharland Norris of Jorge Scientific Corporation.

Note: To receive a copy of the presentation materials, please contact Dr. Philip Chen at:philip.chen@gsfc.nasa.gov.

Meteoroid and Debris Database

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Search Area - The search area offers the user the ability to search for impact feature information based on the LDEF Bay (A-H), Row (1-25*), Component Type (Frame, Experiment Tray, etc.), Substrate Material Type (Al, Teflon, etc.), and Feature Size (diameter in microns); the resulting data can be sorted by either Feature Number or Feature Size. It should be noted that although the new Web Browser interface is easier to use than its predecessor, some searches may return a potentially large amount of data which may cause a user's browser to hang up for long periods of time. Such problems are the result of hardware limitations of the end user's machine, and not the database itself. For this reason, a maximum of 350 records will be returned as the result of any single search. To circumvent this limitation, users are encouraged to limit searches such that the results do not exceed 350 records. This can be accomplished by limiting individual menu to obtain complete or various partial data sets.

Download Area - This area permits the end user to download the complete database (i.e., 22,365 records), or several statistically significant data sets. All downloads are TAB delimited ASCII files suitable for import into a spreadsheet or database application. Note that since the columns are separated by TABS in these files rather than spaces, the headers of each column of data will not appear to line up correctly when viewed on-line with your browser. However, when imported into a spreadsheet application, these values will align properly. For most browsers, these files may be saved to your hard drive by selecting "Save As..." from the File menu.

Specifically, the downloads available are:

Features Table - Contains every feature record in the database.
Primary Surfaces Table - Contains every record in the primary surfaces table of the database.

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prediction models, determine COTS response to single event effects and low dose rate exposure, and improve ground test methodology.

The NASRET consists of a Dosimetry Experiment, COTS 1 (Analog Devices) Experiment, COTS 2 (Digital Devices) Experiment, COTS 3 (Photonics) Experiment, and Pulse Height Analysis (PHA) Experiment. The Dosimetry will measure the observed radiation environment and the effectiveness of composite material and conformal coating shielding technologies; the COTS 1 (Analog) will measure the impact of low dose rate effects and transient Single Event Effects of commercial analog devices; the COTS 2 (Digital) will measure the impact of the radiation environment on commercial digital devices; the COTS 3 (Photonics) will measure the radiation effects on state-of-the-art emerging photonic technology devices; and the Pulse Height Analysis (PHA) Experiment will measure the spacecraft incident energetic charged particles for better Single Event Effects rate predictions.

The Dosimetry Experiment will provide an effective evaluation of the effects from space radiation on the microelectronic experiments. The concept is to accurately determine the electron and proton radiation local environment causing radiation effects in state-of-the-art devices during the mission life cycle. This experiment will provide a technological evaluation and validation of composite materials and conformal coatings for radiation shields. It will also benefit future missions by learning how novel microelectronic devices are affected under accurately characterized space radiation.

The COTS 1 Experiment (Analog Devices) will reduce the uncertainties regarding the space radiation performance of commercial analog devices. It will provide a technological investigation and validation of the COTS analog microelectronic components and their response to the low dose rate environment of space. It will also provide an understanding of the impact of the space single-event environment-induced transients as well as validating the upset rate prediction modeling.

The COTS 2 Experiment (Digital Devices) will reduce the uncertainties regarding the space radiation performance of commercial digital devices as well as increasing the system performance with these types of components. The concept is to measure the radiation effects on state-of-the-art emerging digital technology devices. The main objectives for this experiment are to reduce the future spacecraft size, weight, power, cost, and schedule by utilizing advanced microelectronics technology and to provide a technological investigation and validation of COTS microelectronic components, such as stacked RAMS, ferroelectric RAMS and EEPROMS.

The COTS 3 Experiment (Photonics) will reduce the uncertainties regarding space radiation effects in commercial photonic devices as well as increasing the system performance with these types of components. It will measure the radiation effects on the state-of-the-art emerging photonic technology devices. The main objectives for this experiment are to reduce the future spacecraft size, weight, power, cost, and schedule by utilizing advanced microelectronics technology and to provide a technological investigation and validation of COTS microelectronic optocoupler components.

The PHA Experiment will accurately measure and give a precise definition of the local space single-event radiation environment of the STRV. The PHA instrument will provide the microelectronics investigators with an accurate definition of the measured single-event radiation environment of the STRV satellite. The PHA data will be used to verify and update the single event environment rate prediction and models.

These radiation experiments will develop and validate the advanced microelectronics technology and improve the ground test methodology. Improvements will be made in the accuracy of the environment models, the quality of ground simulations of the environment, and the adequacy of ground testing.

Definition Phase for International Space Station Environmental Monitoring Package

By Stu Clifton, Marshall Space Flight Center

Of major concern to the attached payloads manifested aboard the International Space Station (ISS) are the characteristics of the natural and induced external environment around the ISS and the impact this environment will have on individual experiments. Currently, ground-based modeling provides the only way to assess this environment, and there is an ISS requirement to verify these models by monitoring in situ the various aspects of the ISS environment. In order to satisfy this requirement the Space Station Payloads Office of the Johnson Space Center (JSC) is sponsoring the development of an integrated package of instruments designated the Environment Monitoring Package (EMP). These instruments will measure the environmental constituents around the ISS and verify that this environment is consistent with Space Station contamination control and payload design requirements. The EMP is envisioned to operate as an EXPRESS Pallet attached payload or to be positioned remotely by the Space Station RMS Special Purpose Dexterous Manipulator (SPDM). The measurements are to be made over a five-year period.

The specific primary objectives of the EMP are to support ISS and the payload community by 1) measuring the on-orbit induced molecular environment generated by materials, coatings, and operational systems aboard ISS to assure consistency with requirements specified in SSP 30426, Revision D, “Space Station External Contamination Control Requirements,” 2) measuring the ISS structure potential relative to plasma and plasma properties around ISS to assure consistency with requirements specified in SSP 30420, “Space Station Electromagnetic, Ionizing Radiation and Plasma Environment Definition and Design requirements” and in SSP 30425, “Space Station Program Natural Environment Definition for Design, ” and 3) performing measurements which consider molecular deposition, composition, and local and directional pressure.

As part of the effort, the Marshall Space Flight Center (MSFC) has been tasked to generate a phased approach to the development of this package. The first phase, to be concluded in March, 1998, will define requirements, conceptual design, and resources required by the EMP while the second phase will include the detailed EMP design and development to support a planned launch of EMP on Utilization Flight (UF-4) in early 2002. In the first phase, the top level monitoring requirements for the EMP will be defined and documented in a Monitoring Requirements Document (MRD). In order to define these requirements, the payload user community as well as the SEE Technical Working Group Chairs have been canvassed for input via a questionnaire requesting information on the types and levels of environmental concerns. Additional tasks planned during this phase include the development of preliminary EMP instrument/ system design and carrier interface requirements and the initiation of a conceptual design for the integrated system in terms of carrier capabilities, operations, instrument characteristics, system interfaces and support hardware. The phase will conclude with the planning for the completion of EMP development by defining programmatic requirements, assuring that EMP requirements meet budgetary constraints, and developing a project schedule. While the overall management of the EMP is provided by the JSC Facility and Payload Engineering & Integration Office, at MSFC the project will be managed by the Instruments Development Office of the Earth and Space Sciences Projects Office.

Meteoroid and Debris Database

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Intercostals - Contains feature information from the LDEF Intercostals, which were scanned in detail at JSC.

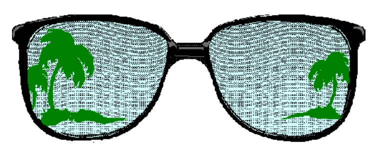
Space Debris Impact Experiment - Contains comprehensive feature information from selected surfaces of the S0001 experiment.

Chemistry of Micrometeoroids Experiment - Contains crater sizes and chemical classification[+] of projectiles from locations A03 & A11.

[*] The LDEF spacecraft possessed 12 rows and two ends. In order to provide a unique identifier to all components, Row numbers of 13-25 were used for certain components on the Earth- and space-facing ends in order to provided a unique identifier to all components. Details of the LDEF numbering scheme can be found in See, T.H., Allbrooks, M.A., Atkinson, D.R., Simon, C.G. and Zolensky, M. (1990) Meteoroid and Debris Impact Features Documented on the Long Duration Exposure Facility, A Preliminary Report, Publication #84, JSC #24608, 583 pp.

[+] The classification and assignment of individual craters to specific projectile types is based on SEM-EDX analyses and interpretation by the experiment’s Principal Investigator.

The Office of the Curator at JSC issues periodic updates on the state of the JSC holdings of LDEF, as well as other meteoroid-related activities, in the form of the Dust Courier. Parties interested in being added to the distribution list of this publication should contact M.E. Zolensky (mzolensk@ems.jsc.nasa.gov).



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- ***The Start of the New Solar Cycle 23***
- ***Evaluation of Space Environments and Effects on Materials (ESEM)***
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- Space Technology Research Vehicle ID: http://see.msfc.nasa.gov/see/strv/strvmain.html
- Space Environmental Effects on Spacecraft: LEO Materials Selection Guide: http://see.msfc.nasa.gov/see/mp/mppub.html
- Sixteen Various other Hypertext Links Spanning Across All Technical Areas.

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